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# APPLICATION OF ADVANCED TECHNOLOGIES IN REHABILITATION PROCESS

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**Abstract:** *Analyses show great progress in developing non-conventional actuators. Artificial muscles have properties suitable for use in the rehabilitation area. The combination of artificial muscle with artificial intelligence gives space to the creation of modern rehabilitation equipment. This article presents a simple rehabilitation device and its control. Emphasis is placed on the usability and implementation of artificial intelligence in this type of devices. There are used neural networks and their application to prediction load during rehabilitation.*

***Keywords: Rehabilitation, pneumatic artificial muscle, artificial intelligence, neural networks.***

## 1. Introduction

An article is aimed to implementation of modern technologies in rehabilitation process. It is concerned with combination of artificial muscle and elements of artificial intelligence in rehabilitation process. Rehabilitation process is time and personal very difficult. There are problems mainly in absence of modern autonomous rehabilitations equipments. Many of equipments used in rehabilitation are just simply modified fitness equipments. This is main reason for development of equipments to simplify individual rehabilitation process. The autonomous device can shorten the rehabilitation period and must be universal so that it can implement a variety of rehabilitation activities. Pneumatic artificial muscles are with their attributes in many cases like human muscles. It is combination of strengthen fibers arranged to system and closed to elastic rubber tube. Both of ends are connected by terminal to mechanical load. Principle of function artificial muscle is simple. There is change of volume by moving of muscle (muscle is increasing) and there is consequently perform power to load. From engineering aspect artificial muscle is relatively simply and has low productions costs. There is a problem with high precision control system based on pneumatic artificial muscles, because there is high non-linearity. Important preference is exact and slow movement between extreme positions of muscle what avoids jerky operation (stick-slip effect) in the start of movement. Next advantages of pneumatic artificial muscles are high reliability and minimal maintenance. Mc. Kibbens Pneumatic Artificial Muscle has power to weight around 400:1 (incomparable with pneumatic piston or DC motor). The disadvantages of pneumatic artificial muscle are: rotational movement needs pair of muscles and big stroke needs long artificial muscles. The pneumatic artificial muscle is meantime underused because there is need of more robust control. Conventional methods for control non-linearity are less applicable, better results are possible to achieved e. g. by using elements of artificial intelligence. (Piteľ et al., 2007), (Havran et al., 2010), (Piteľ et al., 2006).

## 2. Proposal of rehabilitation device based on artificial muscles

Modern rehabilitation systems must meet all terms setting to this type of equipment. A major condition is the safety of a patient who comes into contact with the device.

The design of rehabilitation device consists of several steps, which essentially copied the design of automated equipment procedures:

– analysis of rehabilitation process,

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– estimation of security criterions and safety circuit definition,
– design of construction,
– selection of suitable actuator,
– design of control system and communication interface.

Simple diagram of device is displayed in Fig. 1, which illustrates rehabilitation device and description of several circuits.

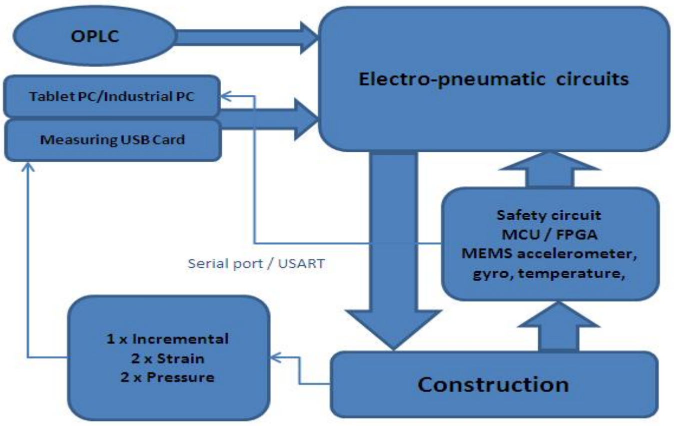



*Fig. 1: Diagram of Rehabilitation Device.*

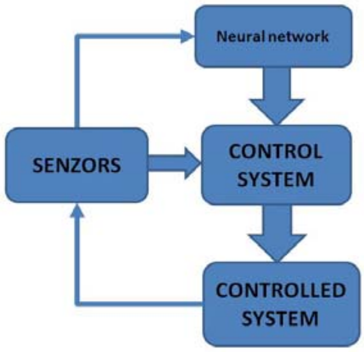



*Fig. 2: Sequence of operation.*

## 3. Proposal of control rehabilitation system with using elements of artificial intelligence

Utilization of artificial intelligence is widely applied in control non-linear system. There are experiments with various algorithms, methods and their combination e. g.: neural networks, theory of learning machines (machine learning), fuzzy logic, genetic algorithms, experts systems etc. How it was mention before pneumatic artificial muscle is unused because of complicated control. Block scheme of neural network implementation for control is visible in the Fig. 2. Rehabilitation device is represented by controlled system. Sensors are transmitting information to control system and neural network. Control system basis on information acquired by sensors and output from neural network regulates load in for rehabilitation process. Application of artificial intelligence in rehabilitation device consists of control of pneumatic muscle and control of rehabilitation movement. Initial testing was realized in Matlab which is suitable for control circuit simulation. There is possible to use combine neural network with another AI element for example Genetics algorithms or Fuzzy-relational network. There is possibility to dynamic change input in neural network and new regulations during learning process. Suitable combination of different sensing element and artificial intelligence is possible to obtain device which will be able to learn and eventually improve. Before rehabilitation start patient must be identified as userXY. After the exercise quit all data will be stored with progresses that it obtain during rehabilitation. With improvement of user fitness, the device alone will increase the load and conversely, if the device recorded the reduction in force it immediately reacts by reducing load (resistance). Such a device is particularly suitable for users who are now after the surgery. Patients will start with minimal of load (resistance) and device will increase load not only according to program but also according to actual patient condition. There are described suitable sensing elements and their combination with artificial intelligence (Sinčák, Andrejková, 1996).

## 4. Application of AI for control of load

Utilization of AI for control load in rehabilitation exercise movement is thought change of pressure in pneumatic artificial muscle. Increasing or decreasing of pressure is changing load which patient has to overcome. This device need for AI control define input and adequate output to NN. Output to NN could get 3 stages: maintain constant load, increase load, load reduction. A value of output depends on several factors that must be ahead known. One of factors can be for example current physical condition of patient, program of rehabilitation etc. Rehabilitation program is in advance known factor which artificial intelligence non-affect. What we need to know to use the AI in this rehabilitation process, we learn from the NN simulation. This NN was developed for management of load of rehabilitation device.

## 5. Definition of inputs and outputs

Input step for Neural network (NN) is definition of inputs and outputs. Outputs have already been described in previous chapter. Values of inputs depend on problem which NN has to solve. If we wish to obtain patient improvements it is necessary to define sense parameters. One of the main inputs parameters is speed. Based on the value of speed captured from device we are able to define current condition. If speed of movement raise without unchanged load from NN it means improvement of condition and it is necessary to increase load. And reversal reduction of speed reacts by decreasing of load. Load changes must be adequate to avoid step changes. In case of a big load increase patient respond by reduction of speed so NN respond by decreasing of load. To avoid described situation serves process of learning. Additional very interesting parameter is direction of movement. Direction of movement is recognized in 2 variants from 180° to 45° grades and from 45° to 180° grades. Direction of movement is important for next upgrading of intelligent rehabilitation device. It is about automatic identification of safety risk. It is situation when patient feels pain during exercise. Primary reaction in this situation is automatic change of direction of movement. NN is able to identify and evaluate safety risk and respond by decreasing load to anticipate potential injury. To recognize this situation it is necessary to know direction in time t and in time t-1. Layout of inputs and outputs is displayed in Tab. 1.

*Tab. 1: NN inputs and outputs.*

| **Inputs** | **Outputs** |
|---|---|
| Speed of movement | Load |
| Direction of movement | |
| Direction of movement in time t | |
| Direction of movement in time t-1 | |

## 6. Simulation of neural network

After the definition of inputs and outputs there is possibility to realize simulation of NN. This Simulation has been made in program Java NNS. Simulation of NN runs in these steps:

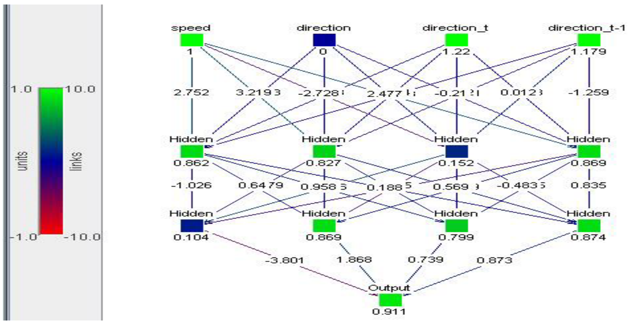
- assigning concrete values to single inputs/outputs,
- developing trained set of data,
- creating and defining of NN,
- developing tested set of data,
- testing and interpretation of NN.

Assigning values to single inputs/outputs is important for correct function of NN. There are assignments of numeric values to status that inputs and outputs could get. The assignment is visible in Tab. 2.

*Tab. 2: The Assignment of values.*

| **Inputs** | **Assigned value** | | |
|---|---|---|---|
| INPUT 1 – speed | constant | going down | going up |
| | 0.5 | 0 | 1 |
| INPUT 2 – direction | 180° - 45° | 45° - 180° | - |
| | 0 | 1 | - |
| INPUT 3 – direction t | 180° | ... | 45° |
| | 1.8 | ... | 0.45 |
| INPUT 4 – direction t-1 | 180° | ... | 45° |
| | 1.8 | ... | 0.45 |
| **Output** | | | |
| OUTPUT – load | constant | go down | go up |
| | 0.5 | 1 | 0 |

Next step is application of assigned values in trained set of data. Application is realized in program Java NNA and created NN is visible in Fig. 3 with described layers.



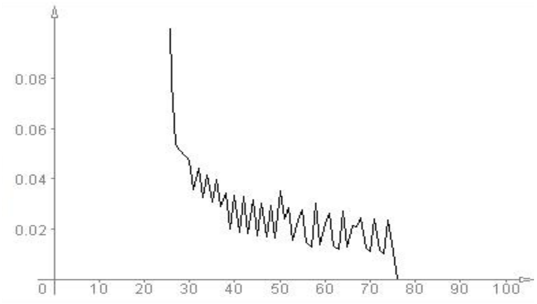




*Fig. 3: Suggested NN.* *Fig. 4: Error graph proposed NN.*

The Learning of NN is working with help of Error graph, with which it is possible to evaluate the learning error. The program offers a selection of several learning functions. It is possible to set up various important parameters during learning of NN, for example number of steps, activation function and similarly. In Fig. 4 is visible Error graph created for neural network. Proposed NN has been able to learn with acceptably mistake of learning in less than 80 cycles. After leaning NN there is time to create set of test data. After creating a set of test data is time for running testing of NN and interpretation of testing NN. Interpretation is running on basis of comparison serious and expected results of classification. It is defined some of coefficients of estimate precision of classification. Coefficient PCC express percentage correct classified vectors from set of test data to all vectors from set of test data. PS is numbers of correct classified vectors and PV is number of all vectors. In this case value of coefficient PSS is equal to 100%. All vectors were classified correct (Fischer et al., 2005).

$$PCC = \frac{P_S}{P_V} \cdot 100 \tag{1}$$

## 7. Conclusions

With development of unconventional actuators and advanced systems of control it was just matter of time when their application penetrates also into the rehabilitation area. Their integration into a specific rehabilitation device based on advanced control and pneumatic artificial muscles is very perspective. Control system of pneumatic muscle has to regulate non-linearity, and there is possible to use AI. Rehabilitation equipment with elements of artificial intelligence can work half or fully autonomous. It is reduces necessary attendance of therapeutics. Simulation of a specific NS pointed to the possibility of using AI in the rehabilitation process. As suitable solution appears to be the neuro-fuzzy systems that combine fuzzy logic and neural networks.

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